Engine Supplier Base Initiative

Casting Sector

PROGRAM LEGACY DOCUMENT

Version 1.0 – 6 October 1998

I. Introduction

The Engine Supplier Base Initiative (ESBI) was established to identify, implement and deploy manufacturing technology that would improve the U.S. industrial base and enhance U.S. international competitiveness in the man-rated turbine engine industry. The casting sector was selected as the first "chain" to attempt a realization of the ESBI vision. This sector was selected partially because of past experience gained by engine manufacturers and casting suppliers working together on related government sponsored programs such as the Investment Casting Cooperative Arrangement (ICCA) and partly on the central importance of casting components to related defense end products.

The focus in the ESBI program is cost avoidance in the government, the original equipment manufacturers (OEMs), and the casting suppliers, as well as on the interfaces between these same participants. Progress is achieved by addressing both process technology and business practice concerns. While the major objective is to reduce the cost of investment cast airfoil and large structural components for man-rated gas turbine engines, major additional benefits of the ESBI effort are believed to be found in:

- A sector wide approach to common problem solving.
- Supply chain alignment of business practices and polices.
- A frontal assault on cultural barriers.

From the program's onset the participants have voiced a desire to go beyond impacts that accrue during program execution to leave in place a legacy built on broadly shared lessons learned and the potential for practicing continuous process improvement. This document is viewed as an element of that legacy. It provides a convenient vehicle for posting the principal (non-technical) lessons learned and articulating consensus conclusions and recommendations.

The intended audience for the document consists of 1) individuals and organizations that that might wish to expand upon or adopt ESBI approaches and methods and 2) the ESBI participating organizations themselves. In order to meet the needs of the second group, this will be a "living" document, with multiple revisions likely to emerge during ESBI program execution.

In addition to this introduction, the document is presented in four sections and an appendix. Section 2 provides relevant ESBI background to set the context for the document and highlights the constraints that largely framed the legacy. Section 3 provides a legacy synopsis as well as the rationale for the breakout of the following section. Section 4 presents legacy component details along thematic lines of working together, methodologies, financial concerns and the ESBI program relationship to "LEAN." Section 5 provides some conclusions and recommendations, and the document ends with an appendix devoted to specific lessons learned examples.

Finally, in proceeding to the next sections, the reader is cautioned not to expect to find a detailed program history or templates for direct replication of ESBI findings. The program history is found elsewhere in the series of quarterly reports delivered to the Air Force sponsor, and direct replication is not meaningful. The ESBI lessons are very much transferable but not directly transportable. Significant tailoring will be in order.

2. Background

This section is intended to provide sufficient background to readers such that they understand the fundamental program aspects that provided the framework for program execution and the resulting constraints upon the development of the program legacy. The background is provided in terms of the general requirements, implementation as a major driver, organizational aspects and finally a recap of specific program goals.

The concept of affordability has become of paramount importance to the Department of Defense (DoD). To date, the majority of the affordability driven acquisition reform activities has focused on government/prime issues and interactions. However, the majority of the cost (and potential for savings) are found at the supplier level. The ESBI was established by the Air Force to reduce the cost and improve the quality of man-rated gas turbine engines and directly addresses the lack of focus on supplier issues. In 1995, the Air Force embarked on an initiative aimed at addressing the affordability of aircraft propulsion systems. Based largely on input from the OEM community at the engine prime level, efforts were initially focused on the investment casting sector for military jet engines, with the intention that other product classes would follow.

From its inception, the ESBI program was intended to emphasize cost reduction activities in the casting supply base by addressing both process technology and business practice issues. For the latter, the major emphasis intended was on improvements in aspects that are common across the government/OEM/supplier sector participants.

One of the major ESBI program drivers and resulting "shaper" of the legacy was the strong commitment among the participants to implementation over development. The direct implication that emerged was on a need to impact foundry processes as the primary levers for improving scrap and rework and as strong contributors to development and cycle time reductions. As a result, what ever else the program did, it was determined that it must touch the foundry floor.

From a procurement perspective, the program is a cooperative agreement between Howmet Corporation and the Air Force Research Laboratory's (AFRL) Materials and Manufacturing Directorate. The program is 66 months in duration. It started in October 1995. The funding is $25,281,153. This is a cost-share arrangement with government contributing $20,000,000, while the industry share is $5,281,153.

Five other companies are linked to the program through a collaborative arrangement with Howmet. The resulting participant set covers the government, OEM and casting supplier elements of the sector. The direct program participants consist of:

- Air Force Research Laboratory
- Rolls-Royce Allison
- General Electric Aircraft Engines (GEAE)
- Howmet Corporation
- Lockheed Martin Aeronautical Systems
- Pratt & Whitney (P&W)
- Precision Castparts Corporation (PCC)

The final ESBI legacy will of course be a function of the program goals and whether or not they are met. These have both technical and business related threads. On the technical side, the program is intended to identify and implement opportunities for eliminating waste in manufacturing operations by the adoption of LEAN practices affecting the quality and cycle time of production components. In addition, the program intends to establish new manufacturing methods through operational innovation, organizational adaptation and process variability reduction. The specific technology goals against which both progress and success are to be measured are:

- Improve airfoil tolerance by 50%
- Reduce structural casting rework by 50%
- Reduce single crystal airfoil scrap by 50%
- Reduce tooling procurement time by 25%
- Reduce production cycle time by 30%
- Reduce new part design and process development by 50%

The program also has the objective of implementing LEAN, non-proprietary business practices affecting cycle time and product quality across the sector.

This is to be accomplished through the execution of certain cooperative endeavors to show the benefits of specific collaborative efforts and by building on those efforts to facilitate the needed broad cultural changes through joint government/OEM/supplier teaming to resolve common business issues.

Industry has engaged in pre-competitive collaboration activities on previous occasions (e.g., consortia activities such as PDES, Inc.) and the Air Force has often sought to help catalyze efforts (e.g., the Lean Aircraft Initiative). However, the ESBI represents a unique attempt at combining collaboration and competitive aspects in an effort to move a full sector forward. The ESBI successfully pulls together the resources of three major engine manufacturers, one air frame manufacturer and the two primary suppliers of precision investment cast airfoils and large structural castings. This program focuses on an industry sector to work cooperatively together to solve problems common to the sector and at the same time integrate highly proprietary process improvements that will produce efficiencies benefiting multiple competitive supply chains. In short, the ESBI

1. shifts from the traditional serial one-to-one partnership to a sector teaming arrangement,
2. seeks to build stable and cooperative relationships internally and externally to implement cultural change in an inter-organizational environment,
3. and represents a decidedly different way of doing things in that the program is OEM directed but supplier led,
4. all in an atmosphere that seeks implemented change in technical and business functions.

3. Legacy Synopsis

The ESBI legacy has multiple components. On an instant contract basis (in this case a cooperative agreement), the cost reductions achieved through product and process improvements and cycle time reductions are extremely important measures of program success. These benefits hinge largely on advances, implementation, and if appropriate, multi-site deployment of manufacturing technology along proprietary lines. Technical advances will be enhanced by the application of lean business practices and the application of enabling technologies with sector wide usefulness (e.g. electronic data utilization) to augment the other technical aspects.

In addition to the meaningful improvements likely to occur over the 75-month life of the ESBI program, a major goal of the program is to demonstrate the usefulness of and create mechanisms for something that exists beyond the "period of performance" for the ESBI participants. The Program Management Team (PMT) captured this idea in a succinct program legacy statement as follows:

Establish the methodology and mechanisms by which the diverse components of an industry sector can cooperatively work together to solve technical and business problems common to the industry and develop an ongoing mechanism for continuous improvement.

Establishing the methodologies and mechanisms for future improvement in the casting sector implies the developing and testing of multiple processes for collaboration. The "what was tried and what happened as a result" aspects of the ESBI experience are in themselves valuable. It is these aspects of ESBI that are captured here.

As the PMT members developed and assessed the lessons learned during the first third of the program, it was recognized that several legacy components were emerging. Assignments were given and a series of "how" papers were prepared on ten loosely defined topics. These were:

1. How competitors can work together
2. How proprietary data is protected
3. How a government/OEM/supplier team is built
4. How rules of the "game" (e.g., behavioral norms) are formed
5. How financial matters are handled
6. How reporting is handled
7. How common goals are established and tracked
8. How a relationship with LEAN is provided and utilized
9. How technology transfer/transition is handled
10. How new initiatives are incorporated or leveraged

As can be seen, the individual topics are not independent. Rather many of them are coupled in one manner or another. For instance competitors working together, protecting proprietary data and technology transfer/transition are strongly related and form the basis for the development of effective behavioral norms. Instead of covering a multitude of discrete topics, the ESBI legacy components will be dealt with along the following lines in the next section.

- Working Together
- Program Execution Methods
- Financial Considerations
- Relationship to Lean

4.0 Legacy Components

The ESBI is all about effective collaboration in the midst of strong competition. The collaboration has both inter- and intra-company aspects. This section discusses legacy component details in terms associated with working together, program execution methods, financial matters, and the relationship of the program to LEAN.

4.1 Working Together

This element deals with the organization structure and basics of team behavior that allow competitors to work together while simultaneously sharing results with customers and implementing changes in “competitive advantage” areas. The overriding consideration is that success on the ESBI program is critically dependent on cooperation among casting suppliers and engine/airframe OEMs who are staunch business competitors. The balance among competition, collaboration and implementation needs has been maintained and built on an ESBI execution structure as depicted in Figure 4.1-1.

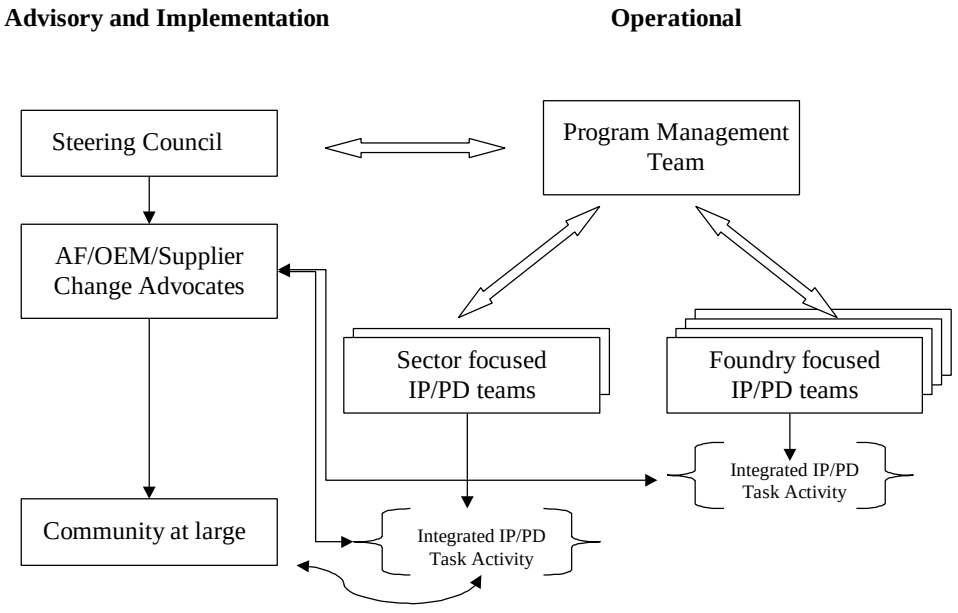

Figure 4.1-1 ESBI Organizational Structure

The figure attempts to show that the program has two essential threads (advisory/implementation and operational) and there is extra care exerted in determining the what, how and with whom aspects of sharing results. Some of the important things to note about the ESBI structure are:

- The primary mission of the Steering Council (SC), comprised of executives from each organization involved in the program, is to advise and provide high level guidance to the PMT on broad (i.e., not project-specific) programmatic issues. The Council members also play a critical role in stimulating the

implementation of program results within their organization and, as appropriate, across the industry sector. They assure positive results are implemented in their respective organizations by either serving in the role of change agent or providing direct links to others, who then serve as the champions for change.

- The Program Management Team (comprised of a representative from each organization involved in the program and for each domain of the program) serves as the operational management arm of the Engine Supplier Base Initiative. The PMT supports the ESBI program manager and is responsible for establishing goals and priorities for projects that offer significant improvements in quality, manufacturing cycle time, and casting affordability. The PMT exercises its oversight and program responsibility by insuring that the teams conducting specific projects within the program are focused on issues consistent with the overall program goals and objectives, and insuring that relevant results are reported. The PMT also incorporates the high-level guidance provided by the SC into the program as appropriate.

- In areas where the rubber meets the road (i.e., project execution) an IP/PD team approach has proven essential. These teams are responsible for the planning, justification and execution of projects that are approved by the PMT. They are made up of experts for a particular task and are divided into two essential classes:

  - Foundry focused teams operate in areas where there is concern about competitive advantage. Teams have been formed within the PCC and Howmet firms and generally follow foundry (factory) lines. The associated technical tasks are largely conducted by people from the foundry where the task is being targeted for initial implementation. It is important that ownership of these technical tasks be with the foundry operations and not engineering or R & D.

  - The sector-focused teams were formed to address two major functional domains where sector progress was thought to be both important and achievable. The domains are Business Process and Policy (BP&P) and Electronic Data Utilization (EDU). BP&P and EDU tasks are more global in scope and generally include one or more members from each ESBI participating organization.

- The rather convoluted set of communication arrows attempts to depict the way in which execution has evolved to meet the combined constraints of collaboration, competition and implementation. Ways were devised to permit the participants to work together in teams that would protect and share proprietary data as appropriate. The product line focus and sector change goal gave rise to such things as a two tiered reporting structure (discussed later), and significant attention to technology transfer.

While foundry technical progress is proceeding as expected, significant progress is also being made in identifying and resolving common, non-proprietary issues that can positively impact price, quality and delivery of military engines/airframes for the U.S. Government. Factors contributing to a cooperative climate within the program are:

- Prior experience among competitors in the industry sector. The DARPA-funded "Investment Casting Cooperative Arrangement" (beginning 1993) comprised a partnership which included Howmet, PCC, GEAE and Pratt & Whitney to improve solidification modeling software and associated applications. This partnership was a "first" for these firms and successfully began the process of breaking cultural barriers to cooperation among business competitors.

- Recognition that competitors have similar problems. The realization, in the most general sense, that competitors (whether casting suppliers or engine/airframe OEMs) face similar technical and business problems encourages mutual respect in program conversations. Such respect is an essential element in maintaining a team approach to ESBI activities.

- Management support for "change." The commitment to change, particularly at the casting suppliers and engine/airframe OEMs, but also in such government initiatives as Acquisition Reform, is so pervasive within each organization that management promptly deals with resistance to cooperation with competitors on common, non-proprietary issues (especially Business Practices and Policies).

- Pent-up demand for action on BP&P issues. The ineffectiveness of one-on-one negotiations between individual casting suppliers and individual OEMs and between individual OEMs and the government on BP&P issues over the years has been extremely frustrating for all parties. ESBI provides a welcome forum for addressing these issues in a constructive, cooperative way.

The ESBI requires team behavior that is different or even "above and beyond" what is routine in the operating cultures of the individual businesses. In addition to working with competitors, members need to openly share information to satisfy customer needs in an atmosphere of trust. A set of "rules of the game" needed to evolve to build multi-cultural and multi-functional teams in a complex environment and to create the conditions for effective program execution. The needed environment has been created to a large degree by focusing on the "customer's" needs and expectations. Members work together making decisions based on facts, striving for consensus as well as making compromises which are aligned with an agreed to ESBI vision. Participants have improved their collective ability to maintain a dialogue on pre-competitive topics and to establish

the process discipline to foster communication to seek common good and avoid the not-invented-here syndrome. The required working level rapport characterized by trust, mutual respect and openness on appropriate topics has increased over time leading to an atmosphere of effectively working together.

4.2 Program Execution Methods

The program execution methods that proved themselves to be valuable in targeting ESBI objectives and providing sector progress mostly evolved over time. Four "methodology" related topics appear worthy of note and are covered in this section. These deal with 1) reporting and the treatment of proprietary data, 2) technology transition/transfer, 3) objective setting and tracking and 4) incorporation of new projects. Note that the first two topics are very strongly coupled.

During program execution, three terms were agreed to (along with multiple processes affecting reporting and operations) that built on the team's common goals.

- Technology transition - the change from what transpired during the ESBI demonstration and validation activities leading to first site implementation or, in the case of unsuccessful results, to the lessons learned bin.
- Intra-organizational transfer - the sharing of results among the organizational bounds of the participants of an ESBI activity. It specifically includes second site implementations and best practice and lessons learned transfer.
- Inter-organizational transfer - the sharing of results to companies and government organizations outside the confines of ESBI activity participants. By its nature the term implies a "re-telling" of the details of the project and activities leading up to results.

It is well to emphasize that both transition and transfer of technology were deemed important to ESBI. However, participants had their own sense of priorities as to which aspect was most important. For instance the primary casting supplier goal is to transition validated process changes that positively impact foundry manufacturing. On the other hand inter-organizational transfer is a major government interest item due to AF ManTech's role in assuring that public funds address public (defense) requirements and their need to avoid "single system" solutions. Finally, the idea of direct technology transition (particularly of the foundry projects) having primacy over research and development is worth extra emphasis. This desire had strong impacts on project selection, execution and reporting.

The ESBI was conceived, constructed, and executed with the idea that both proprietary and collaborative activities would be necessary to meet program goals. The one rule that existed from day one and impacted every other

relationship was that proprietary data would be shared with customers as required but would always be protected.

Since proprietary concerns play a strong role in results reporting and technology transition activities were and are mostly the purview of the Howmet and PCC technical teams, special processes were needed for ESBI execution to assure that rights were protected. The processes had to recognize proprietary positions and still provide the specifics needed for the OEMs to deal with their change agents and AF ManTech to deal effectively with its SPO customers. The result was a two tiered reporting structure that allowed the many meaningful foundry proprietary results to be sanitized, integrated and couched in ways sufficient to meet direct and indirect customer needs while still meeting casting supplier needs. Formal reporting such as that found in the quarterly reports was augmented with “on site” reviews at the foundries to allow real time interaction at necessary technical depth levels with those executing the operational program.

The goal set of swift transition/implementation coupled with government needs to provide standardized/detailed reporting gave rise to continuing reporting problems. The foundry projects were, almost without fail, conducted by personnel with strong operational commitments to “get product out the door.” While they had the requisite desire to execute the projects and directly implement the changes when results warranted it, they had little desire to provide formal progress reports, particularly if they had to strip out proprietary results. The issue was exacerbated from the government perspective by the fact that no hardware was to be delivered on the program. A solution was finally reached by using a standardized project template and relying on the PCC and Howmet technical representatives to the PMT to accomplish required integration and synthesis.

Allaying concerns about proprietary data and establishing the two-tier reporting structure enabled team members to create and build a working rapport, characterized by an increasing level of trust, mutual respect and openness on appropriate topics. These conditions fostered less guarded communication on problems of common interest, promoting first team learning, and then organizational learning from this non-proprietary information exchange.

As part of the program, a separate technology transfer plan was developed. This provided the details of an overall planning approach in terms of participant goals, the constraints, and general guidelines/responsibilities. It was also used to maintain an up to date synopsis of the technology transfer activities and results for each of the major IPTs executing elements of the ESBI effort. Individual (specific) project results (e.g. foundry and business practice and policy managed projects) as well as the major elements of the electronic data utilization team project were reported, with collections of results forming the basis of portions of the program’s legacy. The interested reader should check the plan for specific examples and more detail.

As part of the technology transfer activity a variety of approaches have been

selected to share results outside the ESBI team. Case studies, papers, presentations and advertising have all been attempted in one form or another. For instance, a program brochure has been printed and is available for use. The quarterly reports are being refined as communication tools for broader use within the sector and outside where distribution of non-proprietary portions of reports will be limited to U. S. Government Agencies and their contractors for critical technology. An ESBI web page has been developed for use on the Air Force Research Laboratory ManTech home page. Lastly, based on the feeling that conferences provide an excellent forum for disseminating the collaborative aspects of program progress, a number of written and oral papers have been submitted regarding the program. These activities will be continued through the life of the program.

Challenges associated with objective setting and tracking led to their own set of variation on the ESBI execution methods. As described in Section 2 and elsewhere, specific technical objectives and key lean practices have been developed for and adopted by the program. In the case of the technical aspects these have been a part of the program from its inception. The major issues that have evolved to date are related to the rationalization of the ESBI investment stream on a project by project basis and the generation of a credible story of ESBI impact. The impact element has two distinct aspects. One deals with specific project payoff in customer-focused terms and the other with assigning value of “lean for the sector” aspects of the program. Problems are compounded by a reluctance/inability to deal directly with costs. The ESBI team has chosen instead to use lead-time reduction, cycle time reduction and process variability reduction as the measures of impact.

Multiple attempts have been made to address these issues. These include ad hoc briefings to Air Force management, bellwether parts analyses and detailed value stream analysis in the BP&P arena. All have provided some good but have thus far fallen short. As of this writing, a dual threaded approach is now being attempted. The OEMs are taking the lead in determining the impact of each of the ESBI objectives themselves, with cost avoidance being the preferred metric. The individual IPTs are then providing the recaps of individual project impacts in the metrics that make sense for the project (e.g. specific process improvement, audit reductions, etc.) and relating individual projects to the overarching program objectives via a mapping. The discussions of individual results are augmented with examples of integrated logic (including cost driver analyses) that detail synergism among projects and technology transfer aspects.

The splitting of impact measures allows projects to be judged on their own merits while still providing a view of “big picture change.” A continuing challenge remains in the BP&P area due to the nature of the projects attempted and the difficulty of trying to assign value to such things as the impact of culture change, etc. Selected projects such as the development of sector-wide standard material and process specifications are perceived unequivocally to be “the right thing to

do." However, the combination of the estimated low incremental cost of living with the "as-is" map and the absence of detailed activity-based accounting systems at the casting suppliers has frustrated all attempts to measure implementation benefits quantitatively.

In a program as organizationally complex and of as extended duration as the ESBI is, ways must be determined to "add new projects to the execution menu." In the most general terms, the addition of new projects follows one of three paths:

- First, potential new projects can simply be identified by one of the ESBI teams. Teams identify new projects and initiatives through value-stream analysis, industry studies, lessons learned from active technical projects, brainstorming and input from customers.

- Second, new projects may be initiated by OEM or government program offices. The Program Management Team members keep OEM and government offices informed about progress and, in turn, the feedback from these progress reports generates ideas for new initiatives.

- Third, new projects can be added through project refinement. During project screening, IPT project managers perform risk analysis. As they map out the "as is"/ "to be" scenarios and perform cost/benefit evaluations, it may become apparent that a problem statement needs significant change to be optimized. For collaborative efforts, IPT managers bring this information to the attention of the PMT and the project is canceled, approved with the old objective, or approved with a new objective. Changes in proprietary projects are dealt with in separate PCC and Howmet silos.

The initial projects in each domain (technical, BP&P and EDU) were established independently within their respective domains. Not surprisingly, total integration of these projects in objective, scope or content across the domains could not be crafted retrospectively. Viewed from the evolving perspective of the management of sector-wide programs, total integration of the IPT activities has emerged as an important objective in new project selection. That is, all identifiable technical, BP&P and EDU components should be addressed in the formulation of any proposed new IP/PD project. At this writing, this goal remains elusive as only a thorough value-stream analysis, not yet completed for any proposed project, is expected to yield the requisite integration of all domain elements.

The ESBI program is about implemented change in proprietary areas and new relationships in the engine casting supply chain. The proprietary aspects are user driven but casting supplier controlled. The new relationship aspects relate to barriers to developing mutual trust and commitment among fierce competitors in common areas that do not affect essential elements of that competition. The

relationships are not two-way between companies, but are multi-dimensional among all participants. As a result distinct project selection criteria for the ESBI teams will differ along competitive advantage/mutual collaboration lines. Prioritization, selection and development of specific BP&P projects explicitly recognize the existence and nature of many of the barriers to common problem identification and resolution. With distinct mechanisms for evaluating new projects, the ESBI guarantees that valuable ideas will be identified and introduced into the process.

4.3 Financial Considerations

Large-scale, multi-year, multi-company initiatives present unique financial management challenges. These include standard managing to budget aspects as well as determining how best to meet "re-planning" needs where resources may go from the Company A pot to the Company B pot. The challenges need to be faced and dealt with openly so that financial management problems do not generate a level of uncertainty that jeopardizes progress toward establishing the mutual trust aspects of the ESBI legacy. Taking four simple steps has proven effective in removing uncertainty to the extent that they have been implemented or institutionalized in the program:

- First, the contracting agency must provide the prime and the partners with an accurate timetable for the disbursement of funds for the next fiscal year, as well as the release schedule and amount if incremental release of funds is to be used during the next fiscal year. A predictable flow of funds permits accurate scheduling of the resources required to accomplish planned activities and eliminates uncertainty.

- Second, participating companies must develop the necessary mechanisms within their accounting systems to collect required data on a timely basis. Such mechanisms will insure that accurate invoices can be submitted to the Prime, and in turn, to the Contracting Agency, so that cash flow factors do not adversely impact the program budget.

- Third, the Contracting Agency should maintain an up-to-date account of what has been invoiced in order to accurately track program expenditures. The Prime will take the lead in this matter by submitting copies of invoices to the contracting office and the governmental office responsible for payment. This approach helps close the communication gap between offices, because it provides a running account of invoices submitted and paid along with the data of submission and payment.

- Fourth, to provide motivation for the subcontractors--and the program participants--to submit their billings and progress reports on a timely basis, the Prime should provide payment only when all obligations are met. This

feature of the financial management policy should be clearly defined at the beginning of any future initiatives. Eliminating uncertainty about the disbursement of funding and reporting requirements will help create the business-like environment where energies can be focused on the activities that will result in establishing the Legacy.

4.4 Relationship to LEAN

The operational projects (both foundry and EDU focused) and the BP&P projects in ESBI address directly the elimination of waste in manufacturing which, in the broadest sense, is the basis of LEAN. This section looks at the directly related aspects of LEAN, how they are applied to the program and how they are in turn expanded on by the program.

The Lean Enterprise Model (LEM) was developed as a systematic framework for organizing and disseminating the research results of the Lean Aircraft Initiative. It encompasses lean enterprise principles and practices as well as associated metrics. In addition to a governing set of meta-principles, twelve overarching lean practices are defined. An early PMT analysis of the LEM (as it then existed) showed five of the twelve practices as being especially relevant to ESBI goals and operations. These major lean targets are:

- ASSURE SEAMLESS INFORMATION FLOW - "*Provide processes for seamless and timely transfer of and access to pertinent information*."
- IMPLEMENT INTEGRATED PRODUCT AND PROCESS DEVELOPMENT - *"Create products through an integrated team effort of people and organizations which are knowledgeable of and responsible for all phases of the product's life cycle from concept definition through development, production, deployment, operations and support, and final disposal."*
- DEVELOP RELATIONSHIPS BASED ON MUTUAL TRUST AND COMMITMENT - *"Establish stable and on-going cooperative relationships within the extended enterprise, encompassing both customers and suppliers."*
- ENSURE PROCESS CAPABILITY AND MATURATION - *"Establish and maintain processes capable of consistently designing and producing the key characteristics of the product or service."*
- MAXIMIZE STABILITY IN A CHANGING ENVIRONMENT - *"Establish strategies to maintain program stability in a changing customer driven environment."*

The operational projects use both specific military cast components and critical foundry processes as vehicles for eliminating waste in the casting process. These projects were selected on the basis of LEAN thinking and focus on eliminating the root causes for scrap at various stages in the casting process, on reducing process variability and/or on reducing process cycle time through elimination of redundancies and non-value added activities. EDU efforts expand the elimination of waste ideas across organizational bounds. Projects are aimed at speeding the transition from paper-based systems to a lean paperless

network. Information flow is a special focus as ESBI attempts to develop an electronic product model which flows seamlessly through quoting, engineering, and manufacturing processes. Each operational project has been evaluated with regard to the Lean Enterprise Model to show either a “strong” or “medium” relationship with the target principles of the model.

The OEMs and casting suppliers identified the initial projects under Business Practices and Policies during company process re-engineering. This re-engineering process was based on LEAN thinking and focused specifically on product cost, quality and cycle time criteria. It was recognized that the unique role of the ESBI program provides an opportunity to attack problems at the Government-OEM-Casting Supplier interfaces on a casting sector-wide basis. All BP&P projects therefore explicitly address waste at these interfaces. As with the technical projects, each BP&P project has also been evaluated with regard to the Lean Enterprise Model to show either a “strong” or “medium” relationship with target principles.

While the program tended to adopt/apply lean practices it should also be noted that it really expanded the whole notion of lean. The expansion was related to the development of lean thinking for a sector. A major undertaking of the ESBI was collaborative problem solving for the full aerospace investment casting sector. The development and implementation of sector-wide improvements in business practices equates to finding lean sector approaches that can lead to reduced direct and indirect cost and shorter hardware lead time. Several projects were executed as part of the initiative whose solution offered “lean” benefits were undertaken including problems that would not (and in some cases could not) have been undertaken before. Examples recently submitted for publication include efforts for:

- Development of a sector-wide aerospace investment casting x-ray inspection practice.
- Reducing costs of quality assurance audits.
- Standardizing material specifications and qualification testing.

5.0 Conclusions and Recommendations

As stated earlier, the ESBI program legacy is intended to be supported by a “living document”. As on-going projects conclude and new projects are structured, additional lessons will be learned and various hypotheses formulated and tested. Through all this, new legacy components will likely be developed. The major program conclusions and recommendations will then be revised and summarized in this section. However, based on experience to date, the ideas touched on in the sections above will remain elements of the program legacy, if for no other reason than to document the early steps to beneficial sector-wide cooperation in a competitive business environment.

Appendix A: "Lessons Learned"

1. PMT Mechanics:

- Regular, scheduled PMT Reviews and Meetings at the participating operations are a must; meetings serve as deadlines for accomplishment to project milestones and presentations while tours at participating operations aid understanding of accomplishments.
- The PMT must have a clear understanding of the goals of a meeting/project before starting; productivity at meetings is as important as project productivity
- Make an agenda, stick to it, and come to closure; thorough coverage of topics at meetings simplifies communications when representatives from seven organizations are involved.
- Decisions must be data based; such decisions are much more likely to affect the course of the program than opinion-based judgments.
- Good meeting preparation and participation is required; since decisions are usually based on consensus, representatives must familiarize themselves with issues and alternatives and then contribute to their resolution
- Review the program objective, mission, and goals periodically to make sure that the program is still on track; program focus can easily be lost if the PMT falls into micro-management.

2. IP/PD Team Mechanics:

- Face to face team meetings must be held regularly; interpersonal relationships are an essential element in accomplishing goals that encompass multiple organizations and cannot be fostered adequately by teleconferences.
- BP&P metrics are different from technical metrics; until activity-based accounting is pervasive in the "business" activities associated with manufacturing, appropriate BP&P metrics will continue to be a challenge to identify and incorporate.
- People must not be "spread too thin" at the execution level; intervention at the supervision or management level may be necessary to ensure appropriate priority is given to IP/PD team activities by team members.
- Must have the right people/mix on a team; identification of complementary skill sets is important in IP/PD team formation.
- The team membership must remain stable and comprised of committed people; maintaining team momentum is a challenge when an individual's primary responsibilities lie in manufacturing and related areas.

- Team decisions must be data based; such decisions are much more likely to affect the course of the project than opinion-based judgments.
- Good preparation and participation is required; since decisions are usually based on consensus, representatives must familiarize themselves with issues and alternatives and then contribute to their resolution.
- Establish metrics early in a project along with causal action (by doing this, I will achieve what?); measurable objectives and measurable milestones must be linked in a logical pathway.
- Make an agenda, stick to it, and come to closure; thorough coverage of topics at meetings simplifies communications when representatives from several organizations are involved.

3. Program - General:

- Constant communication to management is critical; alignment of program goals and methodologies with the expectations of both the sponsor (Air Force chain of command) and the program management is essential for "LEAN" execution of the program.
- Constancy of purpose is critical; redirection of elements of the program, whether for form or substance, is costly of resources and negatively impacts accomplishment to program goals.
- The Legacy of this program must be published; "lessons learned" from the early stages of the program should be useful to successor participants on this program and to subsequent sector-wide programs.
- Handouts at a meeting are a must; such handouts ensure more effective communication and allow participants to share information with others in their organization.
- Plant project activities must not be micro-managed; the terms of project accountability are to be communicated at the onset of the project.
- Stay away from form, concentrate on substance; clear communication of expectations in, for example, presentation graphics and report organization greatly reduces non-value-added activities.
- Cultural differences/problems are large and must be overcome; recognition of such differences/problems must be followed by mutual trust and respect if solutions are to be found
- Better program understanding leads to better focus; an up front investment in understanding the expectations for the program, project and/or task pays dividends in efficient execution and in accomplishment.
- Uncertainty must be managed; uncertainty is an element in both the technical and non-technical aspects of programs and projects and requires careful communication, mutual trust and respect and intelligent judgment and action for effective management.